ESTIMATION OF THE AVERAGE DAILY SOLAR INSOLATION FOR ABEOKUTA

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Abstract
Quest for cheap, clean and renewable energy has turned people's interest to solar energy. This wonderful gift of nature is becoming very attractive to the society because of its recently discovered importance to man. Global energy crisis being experienced at the moment is even making it too inviting. Rural populace even needs it more than ever in order to meet its energy demands. Little wonder more attention is focused on solar based research. The intensity of solar energy can not be obtained directly due to lack of adequate equipment. In this work solar intensity for Abeokuta has been computed using Angstrom – Page model. Curves of computed extraterrestrial radiation and solar insolation on a flat surface for the location have also been presented. The values obtained will aid in the preliminary design of solar installations in Abeokuta where solar radiation data are scarce. In this work the optimum solar insolation on a flat surface for Abeokuta is found to be $4.5kwh/m^2/day$.

Key words: renewable energy, rural populace, insolation, daily solar hours

Introduction

Insolation is a measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed as average irradiance in watts per square meter (W/m²) or kilowatt-hours per square meter per day (kW·h/(m²·day)). The given surface may be a planet, or a terrestrial object inside the atmosphere of a planet, or any object exposed to solar rays outside of an atmosphere, including spacecraft. The global-average incident radiation is about 70% of one-quarter of the solar constant; i.e., 240 Watts/m² [1]. However, the average insulation that one gets by dividing the solar constant, which is about 1367 watts/m²[1,2], by the ratio of the surface of the earth to the projected area seen by the sun represents an average over the uninhabited parts of the globe as well as the highly populated regions[1]. The peak radiation received on earth is about 1.0 kW/m² [3]. The total energy received on a horizontal surface, is not uniform throughout the world; the respective values depend on the location and on the climate. The highest insulation values computed as annual totals are found between the two 35° latitude parallels, North and South. In that area there are regions with over 3,000 hours of sunshine per year with direct radiation reaching 90 percent of the annual global. In regions with high humidity and frequent cloud cover, the share of direct radiation falls considerably though the total number of hours of sunshine may be as high as 2,500. In some regions of this area there is little seasonal variation in insolation but there are some with marked variations even though the value of total annual insolation is high[3].

To be able to calculate the yield of a solar energy conversion system it is necessary to know the amount of radiation available at the location of the system, its variation in time and the ratios of diffuse and direct parts. The design and performance analysis of solar systems is frequently based on monthly average daily radiation (extraterrestrial global and diffuse) as well as cloudiness index, K_T, and the diffuse ratio, K_D. In the case of global and diffuse radiation it is a simple matter to obtain the monthly average daily values from available data or from various estimates where data are lacking[1]. The number of surface weather stations recording daily radiation is very small compared with the number recording temperature and precipitation[4]. Detailed spatial analysis of global solar radiation at the earth's surface are needed for estimating the area variation of meteorological, climatological, hydrological and biological processes. So many models have been developed for estimating the availability of solar energy in localities where adequate data are not available. The hourly variations in solar intensity with day of the year during clear weather are shown to follow regular repeatable patterns as noted by Rapp and Hoffman [5]. The demand for solar radiation estimates in Abeokuta is demonstrated by several recent research efforts on solar devices in the locality.

The objective of this work is to use the available data especially the daily sunshine hours for the estimation of the daily solar insolation in Abeokuta for the purpose of design and application.

Methodology

Data Collection

The sunshine data which was the input data for the analysis was obtained from the Department of Water Resources and Agrometeorology. of UNAAB. The available data was for two years only.

Analysis

Angstrom-Page representation (Duffie and Beckman, 1980) is adopted here. It is given by

$$H_m = H_o\left(a + b\frac{n_b}{N_b}\right) \qquad (1)$$

It is implied from equation (1) that the ratio of the monthly average insolation, H_m, to the extraterrestrial insolation at location, H_o, is a function of the ratio of average daily hours of bright sunshine, n_d, to the monthly average of the maximum possible daily hours of bright sunshine, N_b. The parameters a and b are constants. For a tropical climate like Nigeria,

$a = 0.29\cos\phi$, $b = 0.52$ which is the mean value with deviation of 0.005)

(Akinbode, 1992)

$$H_o = \frac{24}{\pi} I_{sc}\left[1 + 0.033\cos\left(\frac{360}{365}n_d\right)\right]\left(\cos\phi\cos\delta\sin\omega_s + \frac{2\pi\omega_s}{360}\sin\phi\sin\delta\right) \qquad (2)$$

(Duffie and Beckman, 1980)

where $\delta =$ declination angle

$\phi =$ latitude of the location $= 7.2^o\ N$

ω_s = sunset hour angle, in degree, it is given by

$\omega_s = \cos^{-1}(-\tan\phi\tan\delta)$

I_{sc} = new solar constant = $1367W/m^2$

n_d = day number of the year

$$N_b = \frac{2}{15}\omega_s \qquad (3)$$

where H_m is the monthly average daily radiation on a horizontal surface. H_o is the radiation outside the atmosphere for same location averaged over the period in question (Duffie and Beckman).

$$\delta = 23.45\sin\left(360\frac{(284 + n)}{365}\right) \qquad (4)$$

where, n = day number of the year.

Results

Table 1 Values of solar radiation for various months in Abeokuta

Month	n_d	N_b	$\frac{n_d}{N_b}$	ω_s	H_o $(KWh/m^2/day)$	H_m $(KWh/m^2/day)$
January	1.69	11.60	0.15	87.19	9.19	3.43
February	3.35	11.74	0.29	88.28	9.82	4.33
March	3.30	11.93	0.28	89.70	10.34	4.51
April	2.00	11.82	0.17	88.85	9.82	3.71
May	3.30	11.66	0.28	87.70	10.23	4.46
June	4.08	12.42	0.33	93.40	10.03	4.57
July	2.64	12.36	0.21	92.90	10.13	4.04
August	1.13	12.20	0.09	91.70	10.34	3.48
September	0.77	12.00	0.06	90.30	10.34	3.32
October	1.10	11.82	0.09	88.90	10.03	3.33
November	1.30	11.66	0.11	87.70	9.40	3.26
December	2.30	11.52	0.20	86.60	8.98	3.54

Fig. 1 Curve of Monthly Average Daily Sunshine Hours for Abeokuta versus Months of the Year

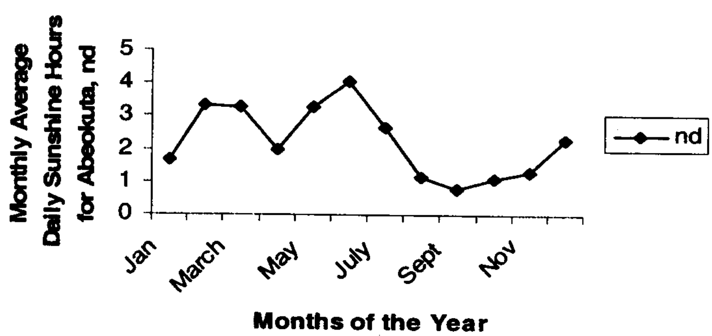


Fig. 2 Curve of Extraterrestrial Radiation versus Months of the Year

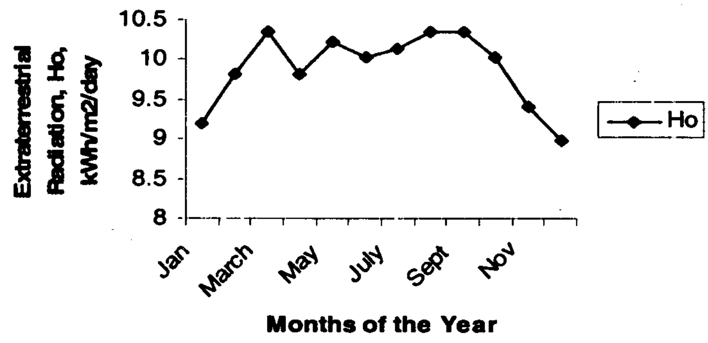
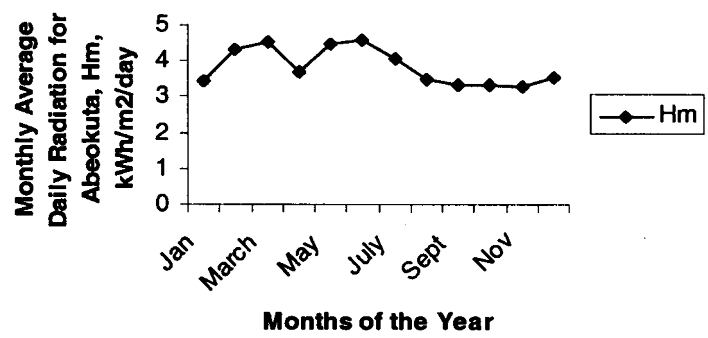


Fig. 3 Curve of Monthly Average Daily Radiation for Abeokuta versus Months of the Year



Discussion

The highest extraterrestrial radiation for Abeokuta (10.34kWh/m^2/day) within the period covered by this study, according to Table 1 and Fig. 2 is recorded during the months of March, August and September while the lowest (8.98kWh/m^2/day) is recorded in December. From Table 1 and Fig. 3, the highest solar intensity on a flat surface for Abeokuta (4.57kWh/m/day) is recorded during the month of June while the lowest in November (3.26kWh/m^2/day). For both the extraterrestrial radiation and radiation falling on a flat surface in Abeokuta, the difference between the maximum and the minimum are 1.36kWh/m^2/day and 1.31kWh/m^2/day, representing 13% and 28% of the maximum respectively. Table 1 and Fig. 1 show that the highest monthly average daily sunshine hours (4.08hours) occurred in June while the lowest (0.77hours) occurred in September.

From the computation relatively high average daily intensity are obtained for February, March, May, June and July. The highest average daily intensity obtained occurred in the Month of June. This looks odd somehow, but can be linked to the climatological changes being experienced globally. This is followed by March which is realistic because it is the peak of the dry season.

Conclusion

With the computation carried out, the highest solar intensity on a flat surface for Abeokuta is obtained to be 4.57kWh/m/day while the lowest is 8.98kWh/m^2/day. With this in mind it can be seen that solar radiation as an alternative source of energy is available almost all year round in this location. The values obtained are available for design analysis and applications.

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